[redacted]

USS-10

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-9299

ST - IGA - CR - 10482

SEARCH FOR HIGH ENERGY PHOTONS FROM DISCRETE SOURCES OF COSMIC RADIO EMISSION

by

A. E. Chudakov
V. L. Ladykin
V. I. Zatsepin
N. M. Nesterova

(USSR)

2 MAY 1966

SEARCH FOR HIGH ENERGY PROTONS FROM DISCRETE SOURCES OF COSMIC RADIO EMISSION *

Cosmic Rays and Problems
of Space Physics
From reprint of unspecified
origin and date. **

by A. E. Chudakov
V. L. Ladykin
V. I. Zatsepin
N. M. Nesterova

SUMMARY

This paper describes the experiment for detecting photons originating from discrete sources of cosmic radio emission. This experiment is based upon the registration of extensive air showers by the Cer nkov radiation emitted by them in the Earth's atmosphere, was carried out in 1960 - 1961. The results are given and dicussed for such sources as Cassiopea A, Taurus A (Crab Nebula), Cygnus A, and a few others.

* * *

It is established at present that there exists in numerous radio emission sources a relatively great concentration of high energy electrons. According to an existing hypothesis, these electrons are the product of interaction of high energy protons and nuclei with the matter.

The detection of high energy photons in these sources would be a direct experimental verification of this hypothesis. Such photons must emerge at interaction of cosmic rays with nuclei of interstellar gas' atoms at the expense of π^0– meson formation and their subsequent decay. Photons may be observed in the direction of the source, for, contrary to the trajectories of charged particles, their trajectories are not distirted in the magnetic fields of the interstellar medium.

Dzh. Kokkoni [1] ventured in 1958 the idea, that if one determined the direction of the cores of extensive air showers of cosmic rays with a precision to $\sim 1^o$, it might be possible to separate the showers induced by primary photons arriving from discrete sources in the celestial sphere.

---

* O POISKE FOTONOV VYSOKOY ENERGII OT DISKRETNYKH ISTOCHNIKOV KOSMICHESKOGO RADIOIZLUCHENIYA.

** [It has been ascertained that this paper is from the Siberian SSR., 1962]

The Kokkoni estimates of high-energy photon intensity from certain objects were found to be overrated. The subsequent theoretical estimates [2] gave the photon fluxes lesser values.

Despite this we attempted in 1960 — 1961 to detect experimentally the photons originating from discrete sources of cosmic radio emission.

The method of the experiment was based upon the registration of extensive air showers by the Čerenkov radiation induced by them. Incidentally, this method was used by us in a series of works in 1953 - 1958 on the study of extensive air showers.

The observations were conducted in Crimea at sea level in clear and moonless nights.

The separation of "photon" showers from the general mass of showers induced by primary photons and nuclei was based exclusively upon the anticipated angular anisotropy of primary photons.

The flares of Čerenkov radiation were registered by photomultipliers disposed in the focus of parabolic mirrors with diameter of 150 cm. Four such telescopes were utilized in 1960, and in 1961, in order to improve their aperture ratio, their number was brought to 12. The general view of the installation is shown in Fig. 1.

Fig. 1

The optical axes of all the telescopes were installed in parallel and oriented toward the point of the celestial sphere through which the object investigated is supposed to pass during a time of ~30 minutes.

Subsequently, an uniterrupted (continous) registration of the intensity of the count of showers was conducted in the course of one hour. The same object could be observed several times during the night by merely "catching" the source by way of telescope reorientation. Later on, all the results related to the given source were summed up.

The anticipated effect must have consisted in the increase of the counting rate at time of object's passage in the visual angle of the telescopes. The visual angle of the optical system constituted $\pm 2^{o}$. The additional widening by 1^{o} of the angular interval in which showers are registered may be expected on account of angular dispersion of the light flux. Thus, the effect of counting rate rise should be searched for within the time intervals of $20 \div 30$ minutes in the case of observation of the object Cygnus A, of $16 \div 24$ minutes in the case of the object Taurus A.

The energy threshold of the installation designed for the registration of showers from primary photons constituted $5 \cdot 10^{12}$ ev in 1960 and $3 \cdot 10^{12}$ ev. in 1961. The counting rate of showers from the charged component of cosmic rays in a solid angle of $^{1}/_{300}$ ster was respectively of 80 and 200 per minute.

<u>RESULTS</u>.- For all the objects investigated, that is, Cassiopea A, Taurus A (Crab Nebula), Cygnus A and Virgo A, plus several other less powerful sources of radio emission, no strong increase in the counting rate was observed. If such an increase does exist, it must not exceed $1 \div 2$ %. The results of measurements of 1960 and 1961 for Cygnus A and Taurus A are respectively shown in Figs. 2 and 3 [next page]. The time relative to the moment of source's passage through the optical axes of the telescopes is plotted in abscissa; α is the direct ascent of the source; the upper histograms on the ordinate axes indicate the total number N of showers counted in the given time interval.

The lower curves characterize the photomultiplier current variation which is conditioned by the passage in the visual angle of telescopes of brighter or less brillant stars.

The effective area of shower registration, defined by the maximum sighting parameter for which the shower is still being registered, constitutes for showers with 10^{13} ev energy, $\sim 10^{9}$ cm^{2}.

Taking into account the statistical precision attained (± 0.02 pulse/s) it is possible to obtain the upper threshold of photon intensity. According to our own data, the photon flux for the indicated objects does not exceed 10^{11} photon $cm^{2}sec^{-1}$. This result is not in contradiction with the estimates of possible flux made on the basis of data on the intensity of the magnetic field and density of the gas in the objects [2].

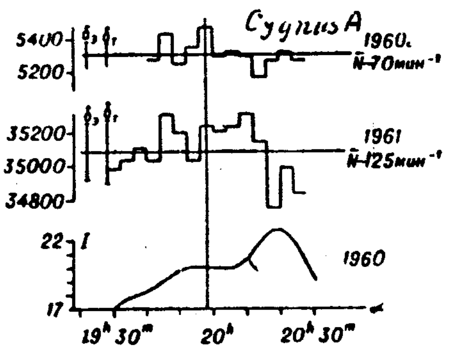

Fig. 2

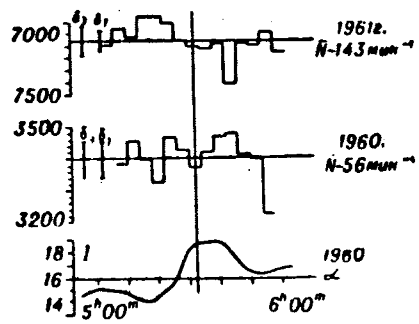

Fig. 3

It is, however, in contradiction with the hypothesis relative to the electrons inducing the synchrotron radiation of the Crab Nebula, as being formed and continually replenished at the expense of nuclear collisions. In this case it should be expected that the flux of photons would be greater by about a factor of 100 than the upper threshold obtained in the experiment. Consequently, the high-energy electrons of Crab Nebula would have been either formed at the first stage of the supernova burst, or accelerated even at the present time by some quite effective meachanism. Both these explanations are met with concrete difficulties.

Measurements of 1960 have revealed a rather small, though quite notable effect of counting rate increase during the investigation of Cygnus A. In connection with this principal attention was given to this object during the 1961 measurements. 70 passages of the object were registered, while more than 500 000 showers were counted.

According to data of 1960 this effect was most clearly outlined in a narrow angular interval (1°) and dropped sharply as this interval widened. Being in contradiction with the anticipated wide angular characteristic (± 2 ÷ 3°), this fact was not confirmed during the recurrent measurements of 1961. Performing the averaging in the wide angular interval, it may be ascertained that in 1960 the effect constituted 1.6 ± 0.8 % for Cygnus A, while the 1961 measurements provided this effect with a value 0.68 ± 0.28 %. The probability that in this case too the positive effect is due to the play of statistics is rather high (2 %).

Therefore, the question of the existence of a flux of photons from the object Cygnus 2, which is detected by our installation for the second time and again at the threshold of statistical precision, may be finally clarified only by subsequent experiments.

**** THE END ****

Institute of Physics
of the USSR Academy of Sciences
in the name of
P. I. Lebedev

REFERENCES

[1].- D. KOKKONI.- Trudy Mezhdunarodnoy konferentsii po kosmicheskim lucham. (Proc. of the Intern.Conf.on Cosmic rays). Izd. AN SSSR., p.327, 1960.

[2].- G. T. ZATSEPIN, A. E. CHUDAKOV.- ZhETF, 41, 655, 1961.

Contract No.NAS-5-9299
Consultants and Designers, Inc.
Arlington, Virginia

Translated by ANDRE L. BRICHANT
on 30 April 1966

DISTRIBUTION

GODDARD SPACE F.C.

100 CLARK, TOWNSEND
110 STROUD
400 BOURDEAU
610 MEREDITH
611 McDONALD
KNIFFEN
GUSS
FICHTEL
BOLDT, VKB
SERLEMITSOS
612 HEPPNER
NESS
613 KUPPERIAN
BOGGESS III
MILLIGAN
STECHER
DONN
HALLAM
614 WHITE
BEHRING
615 BAUER
GOLDBERG HERMAN
MAIER STONE
640 HESS
641 CAMERON
BURLEY
JONES
630 GI for SS [3]
252 LIBRARY
256 FREAS

NASA HQS

SS NEWELL, NAUGLE
SG MITCHELL
ROMAN •
SMITH
SCHARDT
DUBIN
SL LIDDEL
BRUNK
FELLOWS
HIPSHER
HOROWITZ
SM FOSTER
GILL
RR KURZWEG
RTR NEILL
ATSS — T
WX SWEET

OTHER CENTERS

AMES R C

SONETT
LIBRARY

LANGLEY R C

160 ADAMSON
185 WEATHERWAX

JPL

NEWBURN
WYCKOFF

U C BERKELEY

FIELD
WILCOX

U. MICHIGAN

HADDOCK

M.I.T.

BARRETT